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The AMERICAN JOURNAL of OPTOMETRY

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Vol. 13 OCTOBER, 1936 No. 10

CONTENTS

ORIGINAL PAPERS

The Reliability and Variability of the Near Point Accommodative Tests. J. I. Kurtz 361

EDITORIALS

Colored Miral Reflexes. Carel C. Koch 390

BOOK NOTICES

The Prevention and Correction of Reading Difficulties. Emmet A. Betts 397

ABSTRACTS

Foveal Projection During Ductions, and An Objective Study of Binocular Vision. Robert H. Peckham 398

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AMERICAN JOURNAL OF OPTOMETRY

Vol. 13 OCTOBER, 1936 No. 10

THE RELIABILITY AND VARIABILITY OF THE NEAR POINT ACCOMMODATIVE TESTS*

J. I. Kurtz, M.A., F.A.A.O.
Minneapolis, Minn.

I. INTRODUCTION

A. Why this Investigation was Undertaken

Many investigators of the accommodative function are agreed that different results are obtained by testing the same function using different types of tests, hence the findings of one investigator are not at all comparable with those of another. We have long suspected that this is also true when the same function is examined by one person several times, using the same types of test each time. Many clinical workers have been confronted with this difficulty. Howard[1] found that by using the ordinary methods for testing accommodation on candidates for the Aviation Corps that his results were most unreliable.

There are a number of factors contributing to this unreliability. Some of them are:

1. Variation in size of test object.
2. The difference in motive of examination.
3. Variation in speed of approach of test object.
4. Difference in degree and type of illumination.
5. Variation in legibility of test type due either to the size of test type or to the difference in reflection coefficient of the test chart.
6. Difference in position from which the reading distance is computed.
7. The personal equation difference of both the examiner and the subject.

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*This research problem was carried out at the Graduate School at the University of Minnesota Psychology Department. It is part I of a thesis presented to the Distinguished Service Foundation of Optometry.

We wish to acknowledge our indebtedness to Prof. W. T. Heron of the Psychology Department and to Dr. E. Lyon, Dean of the Medical School for their helpful suggestions and critcism. To the American Optical Company, Southbridge, Mass., for their kindness of loaning us the equipment used in this study. We are especially indebted to Prof. M. A. Tinker for his many valuable suggestions and kind cooperation which made it possible for us to carry out this study in his laboratory.

8. Variation in the way the patient is instructed.

9. The size of retinal image increases as the test type is approached to the eye, the retinal images are more diffused and appear larger, hence these images are more easily interpreted mentally than the more distinct but smaller images. The subject is therefore able to read at a point nearer than that for which accommodation is enforced.

10. As the reading material approaches the eye the lids partly close and thus the narrowing of the palpebral fissure is equivalent in action to a stenopaic slit and is a material factor in the reading ability, especially in cases of astigmatism.

11. When concave lenses are used to test accommodation the size of the retinal images are reduced considerably and this affects the amount of accommodation the subject is to exert at a given distance.

Review of the Literature

In reviewing the literature we find that several observers were aware of this difficulty and tried to attack this problem from different angles.

Howard[1] devised a simple apparatus which consisted of a hood with an observation aperture for one eye, a wooden rule calibrated in millimeters is attached to the hood, a set of test letters carried in an object carrier. The letters of the test objects were of two different sizes of test type: 0.8 and 1.2 millimeters. Howard claims with this new apparatus he was able to get more accurate results than with any of the former methods used. He fails, however, to give any data which indicate the degree of accuracy obtained in comparison with any other type of test.

Lee[2] also complains that our present day methods for testing accommodation are unreliable. He devised a simple apparatus, which he claims if used with proper precaution will make it *possible to determine accurately* the range of accommodation, and the maximal near point of accommodation but he also fails to give any data to substantiate his claim.

Thorne[3] being confronted with the same difficulty as Lee and Howard devised a simple apparatus to measure the accommodative convergence and pupiliary distance. He used a Prince rule made out of metal tubing so formed at one end that it will rest comfortably on the bridge of the nose. In the center of the rule there is a convergence object which can be moved back and forth and on each side of the rule there is a movable test card carrier and this enables one to test the accommodation of each eye separately. Thorne claims to be able to obtain very accurate results in making his tests of accommodation but he too fails to produce any evidence to substantiate his claims.

Dr. Edward Jackson[4] who is considered to be the dean of Ophthalmology in the United States, stresses the importance of making an accommodation test in all patients old as well as young who present themselves for an eye examination, as this test can supply information about the strength and endurance of the general muscular system. Upon

this point we can all agree with him. Jackson, however, failed entirely to recognize the difficulty of making an accurate accommodative test when he stated that the actual making of a near point test is very simple. He states "just hold a Jager number one type card about one-half meter away which is the point suited for clear vision, then bring it close to the eyes until it is no longer possible to read it, no matter how much effort we put forth." Measuring this point will give the correct accommodative near point. Jackson evidently failed to take into consideration any of the numerous factors we outlined above, which tend to make this test inaccurate, a fact which was long recognized by most clinical and laboratory observers.

Blatt[5] is convinced that the ordinary tests for amplitude of accommodation that is bringing a card with small size type near to the eyes is not accurate nor reliable. In order to investigate this subject further he constructed an "accommodatometer" which is a considerable improvement over the apparatus devised by Howard[1], Lee[2] and Thorne[3]. Blatt gives some quantitative evidence about his findings with the "accommodatometer"; however, he failed to have made these same tests using any of the other methods which he holds to be unreliable, this would have enabled him to make some direct comparisons as to the amount of variability and reliability between the two methods of testing accommodation.

The different apparatus and technics for testing the near point of accommodation which we mentioned previously are all subjective methods.

A. J. Cross[6], one of the pioneers in modern optometry, realizing the pitfalls of the subjective accommodative tests, set out to discover an objective method. In 1901 Cross gave to the world "Dynamic Skiametry," an objective method for testing accommodation. At first the "Dynamic Skiametry" technic, like most everything else that is new, was crude. Many optometrists tried to use this method in their ocular examination, as advocated by the discoverer, but some of them soon had to abandon it, because while the findings with this new method appeared to be correct theoretically, they could not be utilized practically. It was not until 1917 when Sheard[7] through a series of experiments was able to arrive at conclusions which helped in the interpretations of the dynamic skiametry findings and thus make them practical for clinical application. A number of other workers in optometry notably Tait[8], Bestor[9], McFadden[10] have through their studies and experimentations further developed and simplified the interpretation of dynamic skiametry.

B. Purpose of the Investigation

The importance of making near point accommodative tests is realized by modern clinical refractionists, both optometrists and ophthalmologists. Blatt[5] claims that besides the weakness of accommodation caused due to structural changes there are other causes which bring about not only direct but also indirect alteration of the function of the ciliary muscle and that all the total or partial paralysis of accommodation

are linked to the centrally or locally decreased function of this muscle. He states that some manifest paresis of accommodation can be proven to be due to the paresis of the ciliary muscle, but not every paresis of the ciliary muscle produces a manifest paresis of accommodation. A patient with accommodative asthenopia who can not use his eyes at near may still have a normal near point. Blatt further claims that in some cases the near point will be normal at first and will recede constantly on several successive tests at a few minutes interval apart.

The question is repeatedly raised why a patient with weakness of ciliary muscle can show a normal near point when the eyes are rested and why does the near point recede further and further on repeated tests in case of weakness of accommodation, and why does he easily tire when using his eyes for near work for any length of time? He gives in this connection two points of differential diagnosis which are of interest:

1. Paresis of accommodation entails a loss in the manifest part of the amplitude of accommodation.

2. Weakness of accommodation entails a loss in the latent part. In this case there is a recession of the near point following only fatigue of the eyes, while in paresis of accommodation it is present even after rest.

Numerous other workers in this field stress equally the importance of knowing exactly the condition of the accommodative mechanism before one makes a diagnosis and prescribes for this condition.

C. The Problem

From the above discussion we can see the importance of a more accurate knowledge about the behavior of the accommodative apparatus, and about the reliability and variability of our clinical findings in testing this condition. The following problem "The Reliability and Variability of the Near Point Accommodative Tests" thus presents itself. In investigating this problem we are interested to find some information about these points:

1. What is the minimum amount of amplitude of accommodation?

2. What is the maximum amount of amplitude of accommodation?

3. What is the minimum amount of negative accommodation?

4. What is the maximum amount of negative accommodation?

5. Is there a variation in the above findings when the tests are made monocularly and binocularly?

6. What agreement is there in the negative accommodation findings using different tests?

7. What agreement is there in the findings in the amplitude of accommodative using different tests?

8. Which one of these tests is the most or least variable?

II. THEORETICAL CONSIDERATIONS

A. The Mechanism of Accommodation. There are prevailing at present two theories of accommodation, namely the Helmholtz and Tcherning Theories.

1. The Helmholtz theory (the one most generally accepted) states that the lens is flattest when the eye is in state of rest due to the traction of the suspensory ligament on the edges of its capsule, and is thus focused for distance. When the ciliary muscle contracts it releases the traction of the suspensory ligaments and this allows the lens to return by its elasticity to its more spherical form.

2. The Tcherning theory. Tcherning contends that the changes in the curvature of the lens is more complete than Helmholtz describes. During accommodation Tcherning claims that there is not only an increase in curvature in the center of the lens but at the same time a decrease in the curvature at the periphery. These changes he holds are produced by the increase in the tension of the zonola during accommodation. This is exactly the opposite to the contention advanced by Helmholtz.

While the Helmholtz theory is more generally accepted, of late, however, the validity of this theory has been seriously questioned by Linsay Johnson[11] and Duane[12]. The latter carried out some special research on this problem and concludes that the Helmholtz theory will have to be modified in order to harmonize with the facts.

B. Structure of the Accommodative Mechanism

1. The ciliary muscle is made up of two separate sets of muscle fibers: the radial or longitudinal fibers are the more superficial. They originate from the sclero corneal junction, and are attached to the anterior part of the anterior coat behind the ciliary process. These fibers draw the choroid forward and inward when they contract. The circular fibers tie in the base of the ciliary process so that when they contract they cause the appieces of the process to come together. The ciliary muscles have a common action, causing the ciliary processes to form a smaller circle.

2. The suspensory ligaments (or zonala of Zinn) is formed of a large number of very fine fibers which run from the ciliary process to the capsule of the lens. When the ciliary muscle is in a state of rest the tension in the choroid set up by the intra ocular pressure causes the ciliary process to be pulled in an outward and backward direction and therefore put tension on the lens capsule through the zonola. The lens when accommodated for distance tends to be flattened. When the ciliary muscle is stimulated the tension in the choroid is opposed and the ciliary process approximated. The suspensory ligament becomes slack and the tension of the capsule decreases thus allowing the lens to become more curved and focuses the rays from near objects.

3. Accommodation and ciliary contraction. How much of the total ciliary must one contract in order to produce an accommodative result? Landholt, Donders, Clark and Duane hold that if a person has, for instance, 14 diopters of accommodation, he has to contract only a small amount of the ciliary muscle to increase his refraction one diopter, and when a person reached the age when he only has one diopter of accommodation left he has to use a maximal ciliary contraction to produce this effect. Fuchs[13] differentiates between the physical and physiological near point. The "physical near point" he claims is the result of the accommodation as limited by a physical condition, i.e., the elasticity or the flexibility of the lens. This is the normal near point which recedes with age. The "physiological near point" is the point which could be reached if accommodation was only limited by the contractibility of the ciliary muscle. This point could be reached if the lens was perfectly elastic.

4. *Correlation of Pupillary Reflex with Ciliary and Fixation*

Reflexes. When accommodation is active a contraction of the pupil takes place. Convergence usually accompanies accommodation. There is no definite knowledge as to the definite relationship of the above mentioned three reflexes. We do know, however, that when the accommodative and convergence reflexes are active the pupillary reflex is also caused to be active. While we do know something about how we accommodate we are at a loss to explain why we accommodate, this has all too often been taken for granted, claims Loeb[15] without asking any question as to why we accommodate and what phenomenon takes place when an object is moved from 6 meters to 1 meter and vice versa.

III. EXPERIMENTAL

A. Laboratory and Illumination

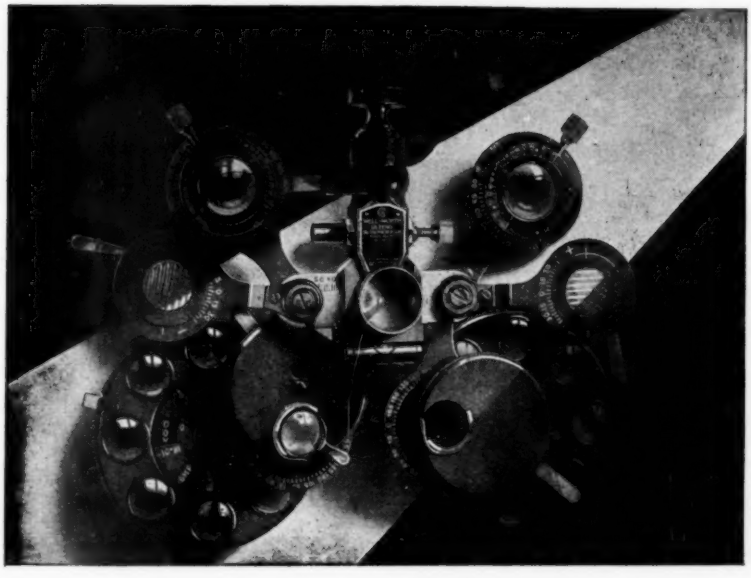
The experiment was carried out in the laboratory at the Psychology Department at the University of Minnesota which was provided with all the necessary equipment needed to perform a complete refraction quite similar to the type performed clinically by any modern refractionist. The illumination was kept constant between 12 and 18 foot candles and was reduced somewhat only during the time when the dynamic retinoscopy tests were performed.

B. Apparatus and Equipment

The apparatus used in making the different tests in this experiment consisted of:

1. Phoroptor—this instrument, Figure 1, was kindly loaned to us for this study by the American Optical Company, Southbridge, Mass.

2. The Tait Dynamic Skiascope. This instrument is used to make both distance and near point skiascopic tests and to determine objectively the amount of negative accommodation. This instrument which is



Dr. J. I. Kurtz. Figure 1. The Phoroptor.
[Courtesy American Optical Co.]

illustrated in Figure 2 may be used in connection with current control so as to enable one to regulate the amount of current to be used or with a battery handle.

3. Cross Cylinder Auxiliary Lens Set.

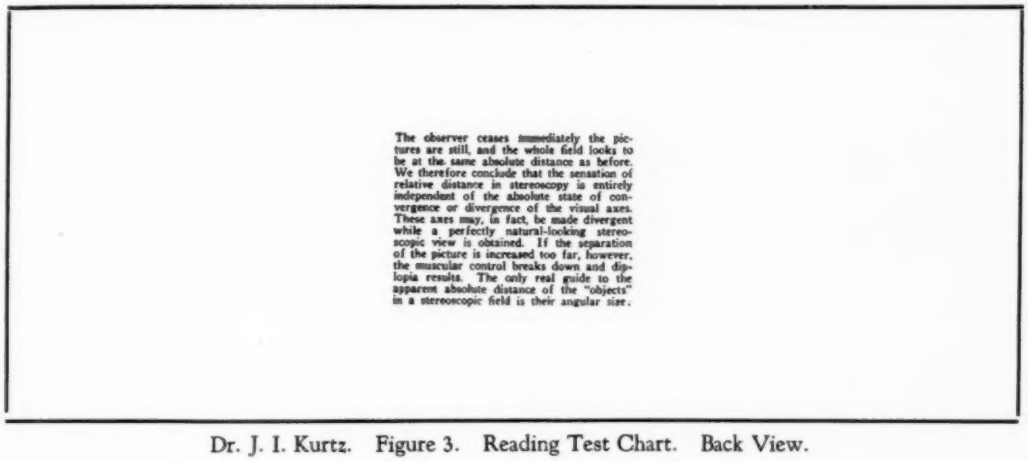
4. Test Cards. A reading card with very fine type was used. The card was about 140 mm. x 110 mm. in size. One side had one column of type 30x20 mm. in size and was used to make the binocular test where both accommodation and convergence were used as shown in Figure 3. This column of type was doubled through the use of a prism placed base down over the right eye. The other side of the same card had two columns of type 30 mm. wide and 97 mm. high and 55 mm. apart. The right column was used for the right eye and the left column for the left eye as illustrated in Figure 3a. In this test each eye was tested separately and accommodation alone was used but not complete convergence.

b. Duane Line Card.—This card is of the same size as described above with this difference: on one side we only used a single very fine line 3 millimeters long and 0.2 millimeters wide, and on the other side 2 lines of the same size 70 mm. apart.

c. Cross Cylinder Card.—This card is the same size as the other two just described. On one side there were five vertical lines 25 mm. in

Dr. J. I. Kurtz. Figure II. The Tait Dynamic Skiascope.
[Courtesy American Optical Company]

length spaced 1.5 mm. apart and five lines of the same size passed through the center horizontally the same distance apart forming a cross, as given in figure 4. On the other side of this card there were two such crosses 60 mm. apart. For the binocular testing that side of each card was used that had only a single object and for monocular testing the other side which had two test objects was used, illustrated in Figure 4a.



The observer ceases immediately the pictures are still, and the whole field looks to be at the same absolute distance as before. We therefore conclude that the sensation of relative distance in stereoscopy is entirely independent of the absolute state of convergence or divergence of the visual axes. These axes may, in fact, be made divergent while a perfectly natural-looking stereoscopic view is obtained. If the separation of the picture is increased too far, however, the muscular control breaks down and diplopia results. The only real guide to the apparent absolute distance of the "objects" in a stereoscopic field is their angular size.

Dr. J. I. Kurtz. Figure 3. Reading Test Chart. Back View.

The following experiment will illustrate some important conclusions. A stereoscopic reconstruction is obtained by fusing two pictures in a stereoscope; the pictures are two projections made in any suitable way, and are mounted separately so that they can be moved independently of one another When fusion has been obtained they are moved slightly apart. It is found that in the duration of the movement the whole field appears to retreat; if they are made to approach each other the field appears to draw nearer, but such apparent movement from or towards the observer ceases immediately the pictures are still, and the whole field looks to be at the same absolute distance as before. We therefore conclude that the sensation of relative distance in stereoscopy is entirely independent of the absolute state of convergence or divergence of the visual axes. These axes may, in fact, be made divergent while a perfectly natural-looking

Stereoscopic view is obtained. If the separation of the picture is increased too far, however, the muscular control breaks down and diplopia results The only real guide to the apparent absolute distance of the "objects" in a stereoscopic field is their angular size; the stereoscopic sense gives an impression of their relative distances, and this results through the variation of the binocular parallax, but, as mentioned above, this is limited in amount. The essence of the stereoscopic sensation is the binocular parallax arising in the different perspectives presented to the two eyes; it cannot arise when both eyes view one and the same picture; but pictures in different colours may be projected on the same screen, as in red and blue-green If then the eyes are furnished with colour filters transmitting only these regions of the spectrum, the two pictures (which may be two suitable perspectives) may be combined visually

To produce stereoscopic results. Alternatively, the two pictures may be printed in inks of red and blue-green to be viewed in a similar way. If a suitable grid is held before a screen, the grid consisting of close equal bars and spaces of equal width, it is possible to arrange matters so that the two eyes view different strips of the same screen (Fig. 113) Thus two perspective projections can be made; one photographed in one set of strips; the other photographed in another set of strips; in this way a stereoscopic effect can be obtained. There seems, however, to be no escape from the necessity of a fairly close relation between the distances of the grid and the observer's head, so that the effect cannot be shown to many people at once. Yet another possibility is to project the pictures alternatively on the same screen, providing the observer with a rotating sector disc to obscure the eyes alternately so that one eye views.

One set of pictures only Perfectly satisfactory stereoscopic effects can be obtained in this way, but the necessity of the sector disc for each person has prevented the system from being used for entertainment purposes. Binocular instruments must necessarily take account of the variations of interocular distance between different individuals, which ranges in adult men from about 56 mm. up to 72 mm. with a mean of 63 mm., the mean for women is somewhat smaller, being about 61 mm. Particulars of measurements may be found in a paper by J W. French. Prismatic binoculars are usually made adjustable between the limits of 57-70 mm., but owing to the much larger eye lenses and exit pupils of Galilean binoculars there is not the same need for the provision of the adjustment, although the necessity of making the glasses usable by a person of small interocular distance limits the diameter of the objective

And, therefore, the field of view Optometry is the science of examining the human eye for the purpose of diagnosing its defects and prescribing proper relief. When variation from the normal length of the eye ball is discovered, glasses are needed and nothing else will take their place There is no substitute for glasses. The eye is a living, changing, highly adaptable organ which can be and often is driven to function long after the margin of safety has been passed. Keen vision often can be accompanied by great ocular discomfort, with headaches, nausea and other distressing symptoms. Thus too much reliance must not be placed upon the sharpness of vision as this is no proof of normal eyesight Proper lenses will change materially the conditions under which those eyes work and naturally there is at first a period of adaptation during which one can expect more or less discomfort before the final

Adjustment is made A periodic examination of eyes that are apparently functioning properly is simply common sense. Eyes with serious defects particularly should be examined at frequent intervals. The Optometrist is a specialist in the scientific examination of the eyes. He has been examined and licensed under the laws of the State for this particular profession The following experiment will illustrate some important conclusions. A stereoscopic reconstruction is obtained by fusing two pictures in a stereoscope; the pictures are two projections made in any suitable way, and are mounted separately so that they can be moved independently of one another When fusion has been obtained they are moved slightly apart It is found that in the duration of the movement the whole field appears to retreat, if they are made to approach each other the field appears to draw nearer but such apparent movement from or towards

Dr. J. I. Kurtz. Figure 3a. Reading Test Card. Front View.

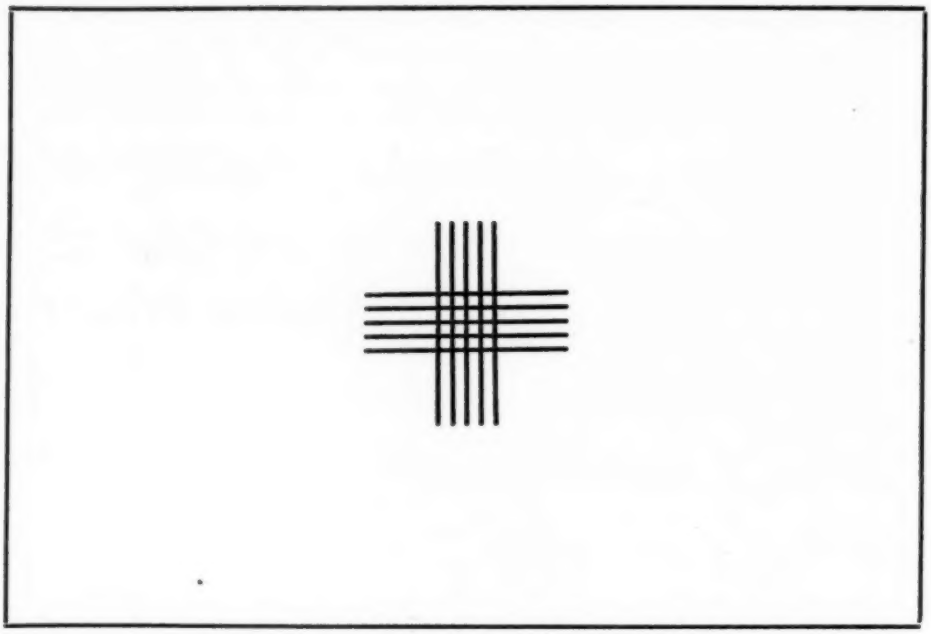


Figure 4. Cross Cylinder Test Card. Back View.

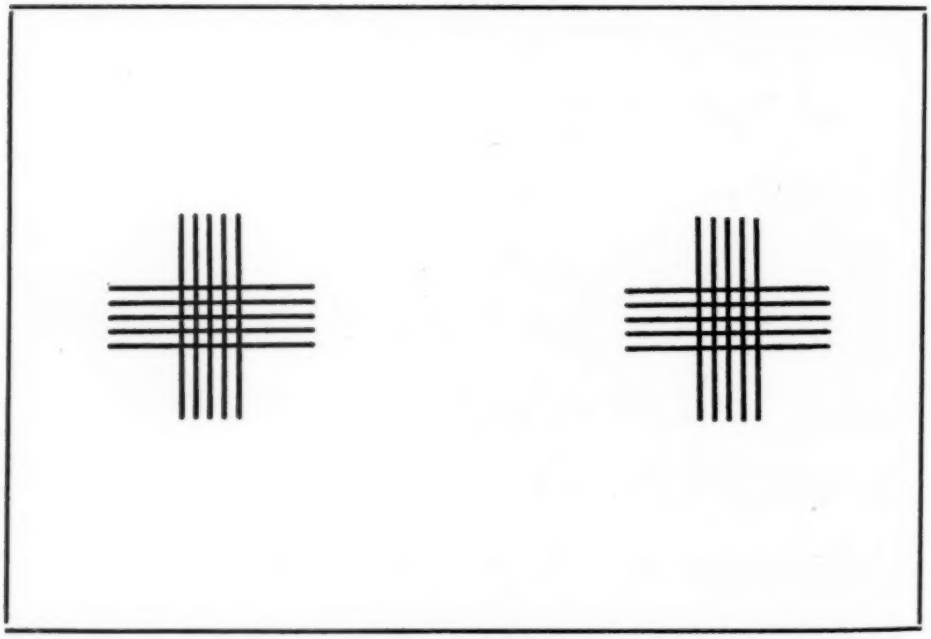


Figure 4a. Cross Cylinder Test Card. Front View.

C. Methods Used for Testing Amplitude of Accommodation

1. Clinical Methods:
   a. Test card with columns of fine type.
   b. Duane line test card.
   c. Minus Spherical Lenses.

When the monocular amplitude was taken with the fine type test card the eye not under test was covered. The column of type was in front and slightly to the temporal side of the eye under test. The card was at 1/3 of a meter from the eye. It was gradually moved nearer to the observer's eye and he was instructed to say "stop" as soon as he could just notice that the type began to get blurred. The distance of this point from the eye was read off on the calibrated rod upon which the test card was held in a carrier and was recorded as the "minimum." The card was then moved still closer to the observer's eye until the type was completely blurred out so that objects could not be read at all. This point was read off again and recorded as the "maximum." The same operation was repeated for the other eye.

The binocular test was performed using the same technic with the exception that the other side of the card was used where there was only one test object. This test object was doubled by using a prism base down in the front of the right eye. The top object being seen by the right eye and the bottom by the left eye. The same procedure and recording was carried out as in the monocular test.

The test with the Duane line card was carried out as described in the above paragraph with this exception that the subject was instructed to say "stop" when the line was noticed to become the "least bit blurred" and the second "stop" point was when the line "doubled" this was taken to be the "maximum."

The test with the concave spherical lenses was made by placing the test card with the reading material on it at 1/3 of meter distance, then concave lenses were placed in front of the eye tested until the print was noticed to become blurred the least amount. This was taken as the "minimum" then more minus was added by turning the battery of lenses in the phoroptor until the type was no longer visible this was taken to measure the "maximum" amount of amplitude of accommodation. In making these three tests a, b and c, it will be noted that all tests were started at the same distance from the eyes 1/3 of a meter, and that test a and b were made by bringing the card nearer to the eyes, while test c was made by keeping the test card in the same position all during the test.

All tests in this investigation were performed first monocular and then binocular and the "minimum" and "maximum" amounts obtained were properly recorded.

D. Methods Used for Testing Negative Accommodation

1. Clinical Method,
   a. Dynamic retinoscopy (objective test)
   b. Plus lenses and Test Card with columns of fine type to be later called the reading card.
   c. Cross Cylinder Test Card with cross lines.

In making the dynamic retinoscopy test monocularly the left eye was occluded while the right eye was tested and vice versa. We first tried to get neutralization of the shadow. The amount of spherical lens taken to bring about this neutralization point was recorded as the "minimum" then more plus was added by turning the proper lens battery in the phoroptor until a point of reversal was reached and the total amount of spherical lens taken to bring reversal of the shadow movement was recorded as the "maximum" amount of negative accommodation.

The test with the "reading card" was also made at 1/3 of a meter. One eye being occluded while the other was tested during the monocular test. Both eyes were uncovered during the binocular test, (this procedure was carried out when we performed any of the tests in this experiment). Plus lenses were placed before the eye under the test until the least amount of blur of the type was noticed. This was recorded as the "minimum" then more lenses were added until the print was so blurred that it could not be read. This was recorded as the "maximum amount of negative accommodation."

The test with "the cross cylinder" card was performed monocularly and binocularly as described above. A "cross cylinder lens" of the combination —0.50 cylinder axis 90⌒+0.50 Cylinder Axis 180 was placed before each eye, under the test. The subject was asked to note if the vertical and horizontal lines on the test card appeared the same shade of darkness. If the horizontal lines appeared darker (as they did in most cases) plus spherical lenses were added until the two sets of lines appeared equal. This amount was recorded as the "minimum." Then nore plus was added until the "vertical lines" appeared darker. The total amount of plus lens before the eye was recorded as the "maximum" amount of negative accommodation.

E. Methods of Work

1. Subjects—Of the 26 subjects used 21 were graduate students at the University of Minnesota and five were not students. Of this group two were optometrists and two were their assistants who understood something about refraction and one was a school teacher. The whole group displayed an intelligence which was above the average and made very good subjects for this work.

All subjects were given a thorough refraction and only subjects with normal eyes or whose refractive error could be properly corrected were accepted.

2. Directions.—Each subject was given complete instructions about the different tests and several trial tests were made first, in order that the subject might know definitely what was expected of him, before the actual experimental test was started. When the reading test card was used either in the amplitude of accommodation or in the negative accommodation tests the subject was instructed to get definitely fixed in his mind as to how clear the type appears so as to be able to tell when the "least amount of blur" appeared. He was then to report "stop." He was next to report "gone" when the type was so blurred that he could no longer read it.

When using the Duane line test card the card was placed in the carrier at 1/3 of a meter distance and the subject was told to observe the appearance of the line and as soon as it appeared blurred the least amount he was to report "stop" then as it was moved nearer to him to report "gone" as soon as the line appeared "double."

When the cross cylinder card was used the subject was instructed to observe closely the appearance of the vertical and horizontal sets of lines. If both sets appeared alike then this was recorded as the "minimum" and lenses were added until the vertical lines appeared darker. The observer was then to report "gone" and this was recorded as the "maximum."

3. Recording Data.

A special set of charts was prepared and all data was recorded on these charts. A sample of these charts along with the raw data as recorded from the observations made on one subject is to be found in the appendix. One chart was used for each of the "six different and complete tests." For instance Dynamic Skiametry is one unit of the six different complete tests. This one unit is in itself made up of four separate tests namely right eye monocular test, left eye monocular, right eye binocular, left eye binocular. In each instance a test was made for the "minimum" and the "maximum." The same holds true for the other five units included in the "complete set of tests." There were 44 individual tests made during the period the six different sets of tests were given (the six sets of tests have already been described. The number of subjects tested, the number of tests made and the number of test periods, etc., are given in Table 1.)

IV. RESULTS

A. Theoretical and Practical Considerations

It may be well to discuss further the theoretical and practical considerations regarding the different tests used in this study of the reliability of the near point Ocular Tests. The problem naturally resolves itself into two distinct parts namely:

1. Negative accommodation both monocular and binocular.
2. Amplitude of accommodation both monocular and binocular.

Statistical Data

1. Total number of subjects	26
2. Average number of weeks each subject was kept under observation	9
3. Average number of "complete sets of tests" made on each subject	26
4. Total number of "individual tests" made on each subject during one complete test	44
5. Average number of "individual tests" made on each subject during the 26 complete tests	1,144
6. Total number of individual tests made on all subjects during the entire period of the investigation	29,744

TABLE 1

Three different methods of testing each function have already been outlined. In view of the fact that these two functions play such an important part in our ocular economy it at once becomes of extreme importance that one knows something more definite and certain about the measuring rod we employ to measure these functions. Supposing that three different refractionists A, B. and C, examined the negative accommodation of a patient X, now if A used dynamic retinoscopy, and B used the reading chart and plus lenses and C used the cross cylinder—will A, B, and C get the same results and if not to what extent may we expect these results to vary? It is exactly these unanswered questions that we are aiming to clear up in this study. It is purely a clinical question, but of extreme importance. Supposing A in testing his patient, is using dynamic retinoscopy finds +2.50 D.S. B using the reading card and plus lenses finds +2.00 D.S. and C using the cross cylinder test finds only +1.00 D.S. While there might be a resemblance between the formula A and B prescribe for this patient, there most certainly will be a great discrepancy in the prescription A and C may give to the patient. It may be argued by our theoreticians that if there is such a discrepancy between the findings of A and C, or B and C that they are each one of them testing a different function, but by advancing such argument one overlooks a very important fact, namely, that under each test the eye is made to perform the same function of seeing at the same distance (33 centimeters) and under the same illumination, hence the accommodative effort required by the eye to perform this function should be the same under each test. If the amount is different in each case, then we may be justified in assuming that the difference is due to some element of variability in these tests.

3. Before we introduce any statistical material about any of the tests let us try and get a clearer understanding about the nature of these

tests. Sheard[16] claims that the contention of Cross was that dynamic skiametry is an objective test of negative relative accommodation. Cross[6] as the inventor of dynamic skiametry, advanced the theory that " a muscle in action and abnormally taxed will accept assistance more readily than a muscle at rest and when normally enervated and normally functioning." He further contended that there is a more or less fixed relationship between accommodation and convergence, the ratio being 3:1 and if accommodation is correlated with convergence in that ratio the eye will maintain that ratio and will relax no more accommodation which break up this harmonious accommodative convergence relationship. Sheard[16] questions this statement by Cross and contends that the ratio between accommodation and convergence is not as rigid as Cross contends but that there is rather a lag of accommodation to the extent of 0.75 D. There is a range of neutral shadow between the first neutral shadow and the reversal of the shadow of approximately 0.75 diopter. In discussing dynamic retinoscopy Davis[17] holds that there is no difference between the dynamic retinoscopic tests and negative relative accommodation. He arrived at this conclusion from the results of examining some 4,500 cases.

The Cross Cylinder test (the technic of its application was described in the preceding pages), is used by many to determine the amount of accommodative effort used at the reading point. Hence the findings of this test should correspond to the findings of dynamic retinoscopy and the reading card and plus lenses test, if these three different methods test the same function. That the results are not the same will be seen from an examination of the experimental evidence presented in the following pages.

Coefficient of Reliability and (B Sr.) Brown Spearman Odd-Even Reliability of the Negative Accommodation

Negative Accommodation	Monocular				Binocular			
	Minimum		Maximum		Minimum		Maximum	
Types of Tests	r	B-Sr	r	B-Sr	r	B-Sr	r	B-Sr
Dynamic Skiametry . .	.99	.99	.99	.99	.99	.99	.99	.99
Plus lens	.99	.99	.99	.99	.99	.99	.99	.99
Cross Cylinder	.92	.96	.98	.99	.98	.99	.98	.99

TABLE 1a

The Odd-Even Reliability of the Negative Accommodation Tests

A study of the reliability of the different tests used in this investigation of the negative accommodation shows that nearly all tests have a reliability coefficient of .99+ with the exception of the Cross cylinder, which has a correlation of .92 for the minimum and .98 for the maximum as is shown in Table 1a. This indicates that the negative accommodation tests are reliable.

Tables 2a, 3b, and 2c represent the results obtained from testing 26 subjects each subject was tested on the average 26 times. In these tables are recorded in diopter values the averages, range and standard deviation obtained from testing the negative accommodation by using the three different tests already described, namely: 1. Dynamic Retinoscopy, 2. Plus Lenses and reading test card, 3. Cross cylinder test.

In the columns A and B of each table are recorded the averages of each subject, in C and D the range and in columns E and F the standard deviation (S.D.) and in columns G, H the Coefficient of variability is recorded. By combining the values of the right and left eye of each subject we have in these columns recorded the results of 52 tests instead of 26. It will be noted in table 2a that there is only a difference in the individual averages of the minimum and maximum dynamic skiametry of between .25 to .50 diopter (to be hereafter abbreviated as D) with an average difference for the entire group of 0.30D. The difference between the minimum and maximum of range is very small, in most subjects the minimum and maximum is the same, in all others there is a difference of about 0.25 D, with the exception of subject number 2 where the difference is 1.00 D. There is an average difference for the entire group of 0.11 D. The coefficient of variation for all subjects is rather uniformly low, the minimum being 12.17 and the maximum 9.79, a difference of only 2.38 per cent.

From these figures we find that there is considerable uniformity in the amount of the difference between the minimum and maximum of the averages, range and S.D. the coefficient of variation being especially low, we may conclude that the monocular dynamic skiametry test yields highly constant results.

In Table 2b we observe by studying columns A and B that there is a considerable variation between the minimum and maximum in the averages. The difference is over 2 D. for subject No. 4, nearly 3 D. for subject 8 and over 3 D. for subject 16. The average difference for the entire group is 0.83 D. The range shows equally wide variations with an average difference for the entire group of 0.33 and there is a difference of 13.29 per cent between the minimum and the maximum of the coefficient of variation. On the whole, there is more variation in this test between the minimum and maximum of the averages, range and coefficient of variation. We may conclude from this that the plus lens reading card test for the negative accommodation, because of its greater variability,

Monocular Negative Accommodation. Dynamic Skiametry Tests.

26 Subjects. 52 Tests on each Subject.

Subject	Values in Diopters — Average		Range		S. D.		% Coefficient of Variation	
	Mi	Ma	Mi	Ma	Mi	Ma	Mi	Ma
	A	B	C	D	E	F	G	H
1.	2.17	2.43	.75	.75	.22	.20	10.14	8.23
2.	3.37	3.62	1.50	2.50	.33	.27	9.79	7.46
3.	3.42	3.67	1.50	1.50	.35	.35	10.23	9.54
4.	3.45	3.72	1.00	.75	.21	.27	6.09	7.26
5.	2.40	2.65	.75	.75	.43	.17	17.92	6.42
6.	1.00	1.24	1.25	1.00	.22	.21	22.00	16.94
7.	2.50	2.76	1.00	1.00	.32	.31	12.80	11.23
8.	3.42	3.62	1.00	1.00	.30	.30	8.77	8.29
9.	3.52	3.82	1.00	1.00	.29	.29	8.22	7.59
10.	2.42	2.67	.75	.75	.24	.24	9.92	8.99
11.	2.63	2.93	.50	.50	.16	.15	6.08	5.12
12.	3.07	3.34	1.00	1.00	.32	.30	10.42	8.98
13.	2.36	2.63	.75	.75	.18	.19	7.63	7.22
14.	3.57	3.97	1.00	1.00	.24	.25	6.72	6.30
15.	2.89	3.15	1.25	1.25	.33	.31	11.42	9.84
16.	3.79	4.12	1.25	1.30	.37	.29	9.76	7.04
17.	3.11	3.37	1.00	.75	.24	.25	7.72	7.42
18.	1.74	2.08	1.00	1.00	.24	.21	13.79	10.10
19.	1.15	1.42	1.75	1.50	.38	.37	33.04	26.06
20.	2.33	2.57	1.25	1.25	.25	.26	10.73	10.12
21.	1.92	2.36	1.25	1.25	.29	.27	15.10	11.44
22.	.98	1.25	1.25	1.25	.28	.26	28.57	20.80
23.	1.50	1.75	.87	.87	.35	.29	23.33	16.57
24.	3.90	4.15	.50	.62	.16	.17	4.11	4.10
25.	5.00	5.25	1.00	1.12	.26	.27	5.20	5.14
26.	2.58	2.85	.50	.50	.18	.18	6.98	6.32
Average for the entire Group	2.70	3.00	1.00	.89	.24	.25	12.17	9.79

TABLE 2a

Monocular Negative Accommodation Tests
Plus Lenses and Reading Card

26 Subjects. 52 tests on each subject.

Subject	Values in Diopters — Average		Range		S. D.		% Coefficient of Variation	
	Mi	Ma	Mi	Ma	Mi	Ma	Mi	Ma
	A	B	C	D	E	F	G	H
1.	2.86	2.86	3.50	3.50	.63	.96	22.03	33.57
2.	2.34	3.36	2.25	1.50	.62	.39	26.50	11.61
3.	2.01	3.04	2.25	2.00	.56	.59	27.86	19.41
4.	2.09	4.16	2.50	1.25	.86	.36	41.15	8.65
5.	1.62	2.78	1.25	1.00	.36	.25	22.22	8.99
6.	1.41	2.14	1.25	1.75	.30	.29	21.28	13.55
7.	2.39	3.20	2.75	2.25	.54	.41	22.59	12.81
8.	1.44	4.23	1.75	1.25	.49	.46	34.03	10.87
9.	2.87	4.49	2.00	.75	.49	.20	17.07	4.45
10.	2.06	3.19	2.75	1.75	.83	.42	40.28	12.17
11.	2.61	3.27	2.38	1.00	.56	.30	21.46	9.17
12.	2.34	3.27	1.75	1.25	.43	.37	18.38	11.31
13.	1.39	2.59	1.75	1.00	.43	.57	30.94	22.01
14.	1.95	4.25	2.50	2.50	.89	.63	45.64	14.82
15.	2.33	3.64	3.25	2.25	.84	.52	36.05	14.29
16.	1.19	4.22	2.75	2.50	.75	.45	63.03	10.66
17.	3.46	3.82	2.01	1.75	.60	.43	17.34	11.26
18.	1.83	2.84	2.00	2.25	.53	.49	28.96	17.25
19.	1.51	2.10	1.25	1.25	.25	.32	16.56	15.24
20.	.61	2.11	1.25	1.50	.28	.38	45.90	18.01
21.	1.90	3.21	2.00	2.50	.46	.45	24.21	14.02
22.	.95	1.63	1.25	1.50	.30	.36	31.58	23.31
23.	2.05	2.55	.75	1.00	.26	.29	12.68	11.37
24.	1.90	2.23	1.00	1.50	.18	.33	9.47	14.80
25.	2.03	3.07	1.75	1.00	.41	.23	20.20	7.49
26.	3.00	3.28	1.25	1.00	.26	.28	8.67	8.54
Average for the entire Group	2.75	3.58	1.97	1.64	.50	.43	27.16	13.87

TABLE 2b

Monocular Negative Accommodation
Cross Cylinder Tests

26 Subjects. 52 tests on each subject.

Subject	Values in Diopters — Average		Range		S. D.		% Coefficient of Variation	
	Mi	Ma	Mi	Ma	Mi	Ma	Mi	Ma
	A	B	C	D	E	F	G	H
1.	.52	2.12	2.50	3.50	.59	.84	113.46	39.62
2.	.44	2.01	2.00	2.75	.52	.66	118.18	32.84
3.	.48	1.52	.25	3.25	.03	.62	6.25	40.79
4.	.28	.93	1.88	1.50	.35	.25	125.00	26.88
5.	.90	1.50	1.00	1.00	.19	.25	21.11	16.67
6.	.04	.91	.25	2.00	.09	.52	225.00	57.14
7.	.19	1.15	1.00	2.25	.23	.49	121.05	42.61
8.	.07	.91	.50	1.75	.14	.40	200.00	43.96
9.	1.08	2.00	2.25	1.87	.53	.55	49.07	27.50
10.	.55	.53	.50	2.25	.13	.34	22.64	64.15
11.	.10	1.24	1.00	2.00	.17	.41	170.00	410.00
12.	.26	.75	1.25	2.00	.31	.40	119.23	153.85
13.	.31	.60	.75	1.00	.16	.25	51.61	80.65
14.	1.47	2.57	3.50	4.00	.87	.89	59.18	34.63
15.	.77	1.34	1.25	1.00	.21	.25	27.27	18.66
16.	.78	1.31	2.00	2.50	.53	.82	67.95	62.60
17.	1.76	3.08	.50	1.25	.32	.29	18.18	9.42
18.	1.33	1.65	1.25	1.25	.27	.30	20.30	18.18
19.	.34	.64	1.00	1.50	.18	.29	52.94	45.31
20.	.11	1.17	1.00	3.00	.23	.66	209.09	56.41
21.	.94	1.70	2.00	2.25	.35	.52	37.23	30.59
22.	.26	.88	1.25	2.00	.28	.42	107.69	47.73
23.	.92	1.72	.87	1.12	.38	.38	41.30	22.09
24.	1.09	2.04	.75	.75	.16	.23	14.68	11.27
25.	1.53	1.57	1.25	2.00	.41	.68	26.80	43.31
26.	0.00	1.34	0.00	1.50	.00	.36	00.00	26.89
Average for the entire Group	1.16	1.43	1.20	1.92	.29	.44	77.83	56.30

TABLE 2c

yields results less constant than the dynamic retinoscopy test. In the Table 2c we see a considerable variability between the minimum and the maximum averages of the individual subjects. Attention may be called particularly to subject 6 with a minimum of 0.04 D. and a maximum of 0.91 D. Subject 8 with a minimum of 0.07 D. and a maximum of 0.91 D. Subject 11 with a minimum of 0.10 D. and a maximum of 1.24 D. Similar differences are found in subject 26 with a minimum of 0.00 D. and a maximum of 1.34 D. Some investigators claim that the cross cylinder test can be performed accurately only on intelligent patients. Tait[8] claims that it is very difficult to interpret the quantitative findings of the cross cylinder unless the patient is very intelligent. The patient's intelligence is no doubt an important factor in the making of a cross cylinder test, but the point most striking in this particular case is that the subject 26 is a student in the graduate school with superior intelligence and ability. Yet on this test her minimum is 0.00 D. and the maximum is 1.34 D. while on the dynamic test her minimum is 2.58 D. and her maximum 2.85 D. and with the second type of test, the plus lens and reading card, her minimum is 3.00 D. and the maximum 3.28 S.

It is of particular importance that a proper evaluation of the cross cylinder test be made, because great stress has been laid about the important value of this test from a clinical and diagnostic standpoint. Several investigators questioned from time to time the accuracy of this test. The writer[18] in a study of the cross cylinder test found that in 86% of the cases the cross cylinder tests were lower considerably than the dynamic retinoscopy test. The reason for this discrepancy may be found in the fact that the cross cylinder test is essentially an astigmatic test in which the interval of sterum[19] is the underlying principle and while it may be a sensitive test for astigmatism it does not serve as a valid subjective test for the negative accommodation.

Table 3 is a summary of the average of the results obtained from tables 2a, 2b and 2c and make easier to get the comparison of the findings at a glance. Summary of results of the monocular dynamic retinoscopy, plus lenses and cross cylinder test of the negative accommodation. The minimum and maximum values of the averages and coefficient of variation are combined and their averages given in columns 1 and 2.

A glance at column 2, Table 3, shows plainly that the coefficient of variability of the dynamic retinoscopy test is 10.83, of the plus lens test is 20.51 and of the cross cylinder test 67.06 per cent. Nearly 7 times as variable as the first test, and more than 3 times as the second test.

Table 4a, 4b and 4c are comparable again. Here the binocular values are recorded from the negative accommodation using the same three tests namely:

1. Dynamic retinoscopy.
2. Plus lenses and reading card.
3. Cross Cylinder.

Type of Test—Monocular	Av. of Minimum and Maximum in Diopters	Coefficient of Variation in %
Dynamic Retinoscopy	2.85	10.83
Plus lenses and reading card	3.16	20.51
Cross Cylinder	1.29	67.06

TABLE 3

It will be observed in Table 4a that in the dynamic retinoscopy test the difference between the minimum and maximum averages is again uniformly small ranging from 0.25 to 0.50 D. with the exception of case number 24, where the difference is 0.78 D. The difference between the minimum and maximum of the averages for the entire group is 0.29 D. For the range the difference for the group is 0.07 D. and the difference in the coefficient of variation is 2 per cent.

In Table 4b the difference between the minimum and maximum in columns A and B the average is small but somewhat larger than the values in Table 4a. The difference in the average for the entire group is 0.75 D. of more than twice the amount of difference found in the dynamic retinoscopy test. The difference in range between the minimum and maximum for the group is 0.14 D. and in the coefficient of variation is 10.53 per cent

In Table 4c we find the same large difference between the minimum and maximum as in Table 2c. For instance in subject 20 we find a minimum of 0.08 D. and a maximum of 1.20 D. Subject 11 a minimum of 0.11 D. and a maximum of 1.41 D. In subject 8 a minimum of 0.19 D. and a maximum of 1.04 D. In subject 3 a minimum of 0.00 D. and maximum of 1.55 D. Particular attention is to be called to the values recorded in the other two tests for subject 3. In the dynamic retinoscopy test he had a minimum of 3.02 D. and a maximum of 3.28 D. In plus lens test the same subject has a minimum value of 1.33 D. and a maximum of 2.45 D. In case of subject number 3 we may call to the attention another point of interest. He is an hyperope of high degree. His average dynamic skiametry findings for the right and left eye is +3.25 D. sphere. This amount is above his regular distant correction which is O.U. +2.50 D.S. Yet on cross cylinder test he has a minimum of 0.00 D. and a maximum of 1.55 D.

The variation in the range of the cross cylinder test is quite marked in a number of the subjects. The difference between the minimum and maximum for the entire group is 0.64 D. The coefficient of variation for this test is rather high, for the minimum of the group being 84.87 and for the maximum 43.35 per cent.

Binocular Negative Accommodation
Dynamic Skiametry Tests

26 Subjects — 52 Tests on each subject.

Subject	Value in Diopters — Average		Range		S. D.		% Coefficient of Variation	
	Mi	Ma	Mi	Ma	Mi	Ma	Mi	Ma
	A	B	C	D	E	F	G	H
1.	2.00	2.25	.50	.50	.14	.14	7.00	62.22
2.	2.40	2.66	1.75	.75	.25	.25	10.42	9.40
3.	3.02	3.28	1.50	1.50	.38	.39	12.58	11.89
4.	3.07	3.33	.25	.75	.24	.20	7.82	6.01
5.	2.29	2.55	1.00	1.00	.24	.24	10.48	9.41
6.	.90	1.11	1.00	1.00	.21	.23	23.33	20.72
7.	2.33	2.61	1.00	1.00	.32	.27	13.73	10.34
8.	2.35	2.60	.75	.75	.23	.23	9.78	8.85
9.	3.17	3.23	.75	.75	.30	.22	9.46	6.81
10.	1.71	1.96	.75	.75	.20	.20	11.70	10.20
11.	2.54	2.78	.50	.50	.11	.11	4.33	3.96
12.	2.81	3.09	.75	1.00	.28	.27	9.66	8.74
13.	2.06	2.31	.75	.75	.19	.18	9.22	7.79
14.	3.16	3.48	1.50	1.25	.38	.32	12.03	9.20
15.	2.61	2.88	1.00	1.00	.26	.27	9.96	9.38
16.	3.16	3.48	1.00	1.00	.28	.27	8.86	7.76
17.	2.49	2.75	1.00	1.00	.20	.20	8.07	7.27
18.	1.77	2.06	1.00	.50	.18	.17	10.17	8.25
19.	1.10	1.39	1.00	1.00	.26	.27	23.64	19.42
20.	2.14	2.40	.75	.75	.18	.19	8.41	7.92
21.	2.00	2.40	1.25	1.25	.33	.29	16.50	12.08
22.	1.04	1.31	2.00	2.25	.36	.39	34.62	29.77
23.	1.64	1.89	.75	.75	.25	.23	15.24	12.17
24.	3.12	3.90	.87	1.00	.40	.22	12.82	5.64
25.	4.87	5.20	.87	1.00	.62	.70	12.73	13.46
26.	———	———	———	———	—	—	———	———
Average for all Subjects	2.39	2.68	1.00	.93	.27	.25	12.50	10.51

TABLE 4a

Binocular Negative Acommodation Tests
Plus Lenses and Reading Card

23 Subjects. 52 tests on each subject.

Subject	Value in Diopters — Average		Range		S. D.		% Coefficient of Variation	
	Mi	Ma	Mi	Ma	Mi	Ma	Mi	Ma
	A	B	C	D	E	F	G	H
1.	3.00	3.51	.93	.89	.13	.12	4.33	3.42
2.	2.78	3.04	2.50	2.00	.47	.43	16.91	14.14
3.	.33	2.25	2.00	1.87	.56	.70	69.70	31.11
4.	2.76	3.73	3.00	1.50	.94	.46	34.06	12.33
5.	.89	2.48	1.00	1.00	.27	.28	30.34	11.29
6.	1.10	1.85	1.75	2.25	.28	.39	25.45	21.08
7.	2.21	3.02	1.25	2.00	.52	.47	23.53	15.56
8.	3.39	4.28	2.25	2.00	.56	.51	40.29	11.92
9.	3.75	4.50	3.00	1.25	.81	.33	21.60	13.64
10.	2.91	3.02	2.75	2.00	.74	.80	25.43	26.49
11.	2.17	3.03	1.75	1.25	.40	.33	18.43	10.89
12.	2.74	3.03	2.25	2.75	.89	.44	32.48	14.52
13.	2.25	2.48	1.50	1.50	.35	.26	15.56	10.48
14.	3.75	4.15	3.00	1.75	.37	.51	9.87	12.29
15.	2.03	3.33	2.50	1.75	.63	.45	31.03	13.51
16.	3.11	4.03	3.00	2.25	.73	.52	23.47	12.90
17.	3.24	3.75	.75	1.75	.47	.39	14.51	10.40
18.	1.91	2.72	1.00	1.00	.46	.27	24.08	9.93
19.	1.41	2.06	1.50	1.25	.33	.28	23.40	13.59
20.	1.55	1.78	1.25	1.25	.25	.29	16.13	16.29
21.	2.13	3.39	2.25	4.00	.44	.50	20.66	14.75
22.	.87	1.45	1.25	1.50	.32	.30	36.78	20.69
23.	1.69	2.28	1.12	1.00	.28	.25	16.59	10.96
24.	——	——	——	——	—	—	——	——
25.	——	——	——	——	—	—	——	——
26.	——	——	——	——	—	—	——	——
Average for the entire Group	2.30	3.05	1.87	1.73	.50	.40	24.98	14.45

TARLE 4b

Binocular Negative Accommodation
Cross Cylinder Tests

23 Subjects. 52 tests on each subject.

Subject	Value in Diopters — Average		Range		S. D.		% Coefficient of Variation	
	Mi	Ma	Mi	Ma	Mi	Ma	Mi	Ma
	A	B	C	D	E	F	G	H
1.	.80	1.24	3.00	4.25	.80	1.02	100.00	82.26
2.	.93	2.10	2.25	2.75	.54	.52	58.06	24.76
3.	.00	1.55	.80	3.25	.00	.61	000.00	39.35
4.	.21	.83	1.25	1.12	.31	.64	147.62	77.10
5.	.94	1.54	1.00	.75	.17	.19	18.09	12.34
6.	.50	.60	1.00	1.25	.20	.27	40.00	45.00
7.	.45	1.26	1.00	.75	.20	.41	44.44	32.54
8.	.19	1.04	1.25	2.75	.23	.64	121.05	61.54
9.	1.27	1.70	2.00	2.63	.45	.62	35.43	36.47
10.	.10	.52	.25	.50	.30	.14	300.00	26.92
11.	.11	1.41	1.00	2.38	.24	.55	218.18	39.01
12.	.19	.53	1.00	1.25	.25	.34	131.58	64.15
13.	.63	.91	1.25	1.12	.31	.33	49.21	36.26
14.	2.55	2.68	3.00	4.00	1.28	1.15	50.20	42.91
15.	.83	1.34	1.50	1.50	.26	.35	31.33	26.12
16.	1.10	1.56	2.75	3.25	.61	.78	55.45	50.00
17.	1.76	3.19	.50	1.25	.29	.31	16.48	9.72
18.	1.22	1.56	1.25	1.25	.25	.28	20.49	17.95
19.	.41	.43	1.00	1.50	.26	.51	63.41	118.60
20.	.03	1.20	1.00	2.75	.20	.60	250.00	50.00
21.	1.10	2.00	2.00	2.25	.44	.48	40.00	24.00
22.	.22	.80	1.25	2.50	.26	.44	118.18	55.00
23.	.91	1.79	.87	1.00	.37	.45	40.66	25.14
24.	——	——	——	——	—	—	——	——
25.	——	——	——	——	—	—	——	——
26.	——	——	——	——	—	—	——	——
Average for the entire Group	.72	1.38	1.36	2.00	.36	.46	84.78	43.35

TABLE 4c

Table 5 is a summary of the average of the results obtained for the entire group in Tables 4a, 4b and 4c. The comparison of the values can thus be made at a glance. Summary of results of the binocular dynamic retinoscopy, plus lens, and cross cylinder tests, of the negative accommodation. The minimum and maximum values of the averages and coefficient of variation are combined and their averages given in columns 1 and 2. The figures in column 2 Table 5 reveal points of interest similar to those found in table 3. Here we find again that the coefficient of variation of the dynamic retinoscopy is 11.51, of the plus lens test 19.71 and of the cross cylinder 64.06. This is nearly 6 times as variable as the first test of this group and more than 3 times as variable as the second test.

Type of Test Binocular Negative Accommodation	Av. of Min. and Max. in Diopters	Coefficient of Variation of the 3 Tests in Per Cent
Dynamic Retinoscopy	2.45 D.	11.51
Plus lenses and reading card . . .	2.67 D.	19.71
Cross cylinder test	1.05 D.	64.06

TABLE 5

Difference Between Monocular and Binocular Negative Accommodation

	— Values given in Diopters —		Difference
	Monocular	Binocular	Between
Types of Tests of Negative Accommodation	Average of the Minimum and Maximum Averages		Monocular & Binocular
Dynamic Retinoscopy	2.85	2.45	0.31
Plus lens and reading card .	3.16	2.67	0.51
Cross cylinder	1.29	1.05	0.24

TABLE 6

The Reliability of the Differences Between the Averages of the Negative Accommodation

Negative Accommodation Tests	Monocular					
	Minimum			Maximum		
	Diff. of Mean	S.D. Diff.	D. / S.D. Diff.	Diff. of Mean	S.D. Diff.	D. / S.D. Diff.
Dynamic Skiametry vs. Plus Lens	.69	.99	.69	.15	.74	.02
Dynamic Skiametry vs. Cross Cylinder	2.06	.86	2.38	1.54	.87	1.74
Plus Lens vs. Cross Cylinder	1.37	.66	2.65	1.70	.72	2.34
	Binocular					
Dynamic Skiametry vs. Plus Lens	.01	.81	.01	.49	.67	.72
Dynamic Skiametry vs. Cross Cylinder	1.53	.66	2.31	1.13	.70	1.60
Plus Lens vs. Cross Cylinder	1.54	.83	1.84	1.62	.81	2.00

TABLE 6a

The coefficients of correlation between the different negative accommodation tests and their P.E. are given in this table for the minimium and maximum values of the monocular and binocular findings.

Tests Correlated	Monocular				Binocular			
	Minimum		Maximum		Minimum		Maximum	
	r	PEr	r	PEr	r	PEr	r	PEr
Dyn. Skiametry vs. Plus Lenses	.27	.13	.64	.07	.47	.10	.60	.08
Dyn. Skiametry vs. Cross Cyl.	.42	.11	.43	.11	.26	.13	.43	.11
Plus Lens vs. Cross Cyl.	.31	.12	.37	.11	.46	.10	.42	.11

TABLE 6b

We have found no reference in literature about the difference in amount between monocular and binocular negative accommodation. It appears from a comparison of the averages of the minimum and maximum values for the entire group obtained from the use of the three different tests of the negative accommodation that the monocular values are somewhat higher than the binocular. In Table 6 we combine the figures from columns 1 and 2 of Tables 3 and 5. Here are found in Table 6 that the amount of monocular negative accommodation is greater than the binocular by 0.31 D. when the dynamic retinoscopy is used and 0.51 D. with the plus lens test and 0.24 D. with the cross cylinder test.

This general agreement of the three different tests would tend to indicate that monocular negative accommodation is greater than binocular in the amount ranging from 0.25 D. to 0.50 D.

In Table 6a are given the reliability of the negative accommodation for the minimum and maximum of the monocular and binocular test. The formula for correlated measures was used in computing the S.D. of the difference. It will be seen that the differences are not very reliable as the ratio of $\frac{D.}{S.D.\ Diff.}$ are all considerably less than 3. This may be due to the fact that the number of cases used in the sample is small.

The Coefficients of Correlation

The coefficients of correlation between the negative accommodation tests as given in Table 6a indicate a very low degree of correlation between the various tests. The highest being .64 and the lowest .26. This is exactly what one might expect when we consider the nature of the 3 tests. The dynamic skiametry being an objective test, the plus lens a subjective and the cross cylinder a subjective test causing a disturbance of the visual images due to the interval of sternum produced by the cross cylinder lens.

General Summary

1. A series of tests were carried out on 26 subjects. The negative accommodation and was tested using three different types of tests.

2. The minimum and maximum findings were obtained in each test. The right and left eye values were combined thus giving 52 tests for the calculation of the average, range and S.D. The coefficient of variation was computed from the average and the S.D. of all the subjects contained in the group.

3. Comparing the results obtained from testing the negative accommodation it is found that the dynamic retinoscopy has a coefficient of variation of 10.83%, the plus lens test 21.51% and the cross cylinder test 67.08% for the monocular tests and 11.51%, 19.71% and 64.06% respectively for the binocular tests.

4. Between the minimum and maximum dynamic retinoscopy for individual averages the difference is between 0.25 D. to 0.50 D.

5. It is also found that the monocular negative accommodation findings are consistently higher on all tests used. The amounts vary from 0.25 D. to 0.50 D.

6. The reliability of all these tests was determined by correlating the odd and even tests, and the coefficient of reliability was found to be .99+ with the exception of one or two instances where it was slightly lower.

7. The three different tests of the negative accommodation were correlated and it was found that the coefficient of correlation was of very low degree for the negative accommodation tests.

9. From the results obtained in the binocular amplitude of accommodation tests it is found that while the coefficient of variation of each individual test is low varying from 8 to 14 per cent. There is found, however, a spread between the minimum and maximum of the averages for the group in each test. The difference is greatest in the Duane line test being 5.28 D. The next highest is the reading card test being 3.60 D. The lowest being the concave lens test 2.33 D. This difference is still more apparent when the binocular findings are considered. The reading card difference between the minimum and maximum is 4.82 D. and in the concave lens test it is 2.42 D.

CONCLUSIONS

1. From these results we may conclude that the minimum and maximum amount of negative accommodation varies depending upon the tests used. That between the three types of tests used the dynamic retinoscopic test is the least variable, the plus lens and reading card test is more variable and the cross cylinder test is the most variable, i.e., about 600 per cent more variable than the dynamic retinoscopy test. We will therefore get the least variable results by using the objective dynamic findings than through the use of any of the other subjective tests.

2. The cross cylinder test because of its very high coefficient of variability (77.83 per cent in the minimum and 56.30 per cent in the maximum monocularly and 84.78 per cent and 43.35 per cent respectively binocularly) is not a proper test for measuring the function of negative accommodation and possibly does not measure this function at all.

3. The difference between minimum and maximum amounts of dynamic retinoscopy is between 0.25 D. and 0.50 D.

4. The monocular negative accommodation is between 0.25 D. to 0.50 D. higher than the binocular. This is confirmed by all tests.

The Clinical Significance of These Tests

The results and conclusions arrived at in this study are of considerable clinical significance. While we find that all of the negative accommodation tests are very reliable, they, however, differ greatly in their variability. Few practitioners today prescribe lenses from the findings of

any single test. They do make use of the negative accommodation tests for the purpose of comparison, they are used as tools for diagnostic procedure. Now if we find that the cross cylinder tests is over 600 per cent more variable than the dynamic and over 300 per cent more variable than the plus lens test we should be .....
on our guard against attaching too great importance to this test, in spite of the fact that it enjoys great clinical popularity and has many advocates.

Any efficient skiascopist knows from clinical experience that when a dynamic skiascopic test is performed and properly interpreted it is possible to arrive at an accurate prescription for the reading point (providing there are no muscular imbalances) from this test alone.

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Part II of this Article in Next Issue

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COLORED MIRAL REFLEXES

In reviewing the literature dealing with the subject of making a corneal reading with the ophthalmometer to determine the presence or absence of corneal astigmatism, one is surprised to find so little reference to the subject of colored reflexes, as observed, when viewing the images of the ophthalmometer mires, as reflected from the anterior surface of the cornea. As is well known to every user of the ophthalmometer, a certain small but well defined percentage of all patients present these strikingly unusual colored reflexes, yet in surveying the literature, little has been presented to the profession to explain this phenomenon. Not only does one search through the writings on corneal astigmatism and the use of the ophthalmometer with but little satisfaction, but one may also search in vain throughout both the medical and optometric literature dealing with the anatomy of the conjunctiva and cornea without finding reference to this condition. This is also true in checking over the literature dealing with the dioptric refractive value of the cornea as the first of the refractive media of the eye, as well as in reviewing the field of optometric refraction and that of the diagnostic value of the objective refractive findings and also the general subject of ocular examinations.

One can search too, throughout the literature on ocular hygiene, radiant energy, diet, ocular pathology and the physiology of vision without finding as much as a mention of this subject, common as it is to every optometrist and ophthalmologist. This is true also in searching the literature dealing with the chemical and biological aspects of ocular work as well as the therapeutic and bacteriological sides. The writer has consulted the writings of the following men, all dealing with some portion of this work, Atkinson, D. T.[49], Atkinson, T. G.[28, 47], Bagwell[52], Beacher[31], Booth[29], Brown[40, 41], Colebrook[13], Collins[55], Coque[46], Cross[18], Darier[54], Drummond[63], Duke-Elder[32, 51, 53], DuPlessis[77], Fisher[36], Goldnamer[45], Harman[30], Hartridge[35], Hathaway[72], Higley[21, 22], Jackman[67], Knapp[56], Laurance[24], Lesser[34], Levin[1, 2, 75], Littlefield[38], Lockwood[16], McFadden[60], MacElree[76], Mason[71], May[58], Maybee[69], Minchin[7], Morrow[76], Neame[50], Neumueller[73], Nott[68], Orendorff[3], O'Rourke[64], Paine[70], Parsons[48], Pascal[17], Peckham[19, 23], Perrigo[62], Posey[78], Roberts[11], Rogers[22], Ryer[6, 66], Sacs[61], Sheard[8, 9], Skeffington[12, 26], Souter[39], Steinfeld[10], Stephen[55], Thorington[33], Tscherning[43], von Helmholtz[42], Whitaker[74], Wiseman[79], Woll[57] and Zoethout[44], without finding as much as a mention of this subject, which may or may not have diagnostic significance.

While, as I have just shown, the great majority of optometric and medical writers ignore the matter entirely, one does find a few references to this subject. For instance, Beach[59], a medical writer, observes that irregularities both in curvature and in luster and evenness of the surface are demonstrated by reflecting a window upon the various areas of the cornea. Changes in the spacing or direction of the bars indicate corresponding alterations in the cornea. Reflections of the mires seen through the ophthalmometer make these even more evident. In this way keratoconus is revealed and foreign particles, strippling, ulcers, pannus and the like. It is evident, therefore, that Beach believes that these colored reflexes observed when viewing the images of the ophthalmometer mires as reflected from the anterior surface of the cornea are symptomatic of ocular pathology. He gives no reason nor proof, however, for this observation.

DeMars[65], an optometrist, writing on this same subject some ten years before Beach, also observed the apparent change in corneal color. DeMars had this to say on this subject: Ophthalmometry, too, has not yet reached the limit of its usefulness. In the using of the instrument you have probably noticed the difference in the shades of corneal color from case to case. At first I thought it was due to the peculiar light in my room at that time, and at other times I found that it could not possibly be that, because these changes in corneal color have occurred in a sequence of cases and there was no reason, from the standpoint of light, that the corneal color should be different. DeMars therefore, while observing the phenomenon made no attempt to explain it.

Ryer[15], another optometrist, discusses this matter in his text book on Ophthalmometry. He says, it seems proper to call attention to this field for research and to urge every optometrist to contribute directly or

indirectly by observing, recording, and as far as possible, interpreting every phenomenon bearing on this phase of the subject which presents itself in his individual practice. According to Ryer, the coloring of the miral reflexes is not easily accounted for. It may be due, he speculates, to chemical changes in the lacrimal fluid or to changes to the texture of the corneal tissue which cause the latter to act as a diffraction grating. A loose texture cornea could be conceived as responsible for the large red waves and at the same time for the myopia on account of its lack of resistance to intraocular tension, whereas a tense cornea would be likely to accompany a highly strung individual and, because of its closely knit texture, send back the blue waves or the steel-gray waves; but while this hypothesis seems plausible it is only offered tentatively, awaiting more definite data. Ryer attempts to account for the changes in color reflexes on the basis of an anatomical or pathological change in the texture of the cornea itself which, if he is correct, would be an important field for further investigation.

Shepard[25], another optometrist, flatly attributes these color changes to ocular pathology, although he presents no evidence to support his statement. He says, pathology of the cornea or of the conjunctiva, or pathological conditions effecting the cornea may be discovered during ophthalmometry. He advises the optometrist to be on guard for the distortion of mire reflections, off-color corneal images or radical changes in ophthalmometer findings, since the previous examination. If such indications are discovered, direct examination of the cornea under magnification, perimetry, and a general search for pathological signs are, he believes, indicated.

Smith[27], a medical refractionist, also suggests that colored miral reflexes may be symptomatic of ocular pathology. He says: a faint stippling, either of the epithelium of Bowman's membrane, too little to be seen with the naked eye, shows up at once in the miral reflex and not only suggests pathology but explains why the vision can not be brought up to normal. Here too, no supporting evidence is given for the suggestion that these colored reflexes are evidence of ocular pathology.

Skeffington[4], another optometrist, suggests that systemic bodily changes may be the cause of the colored miral reflexes although he seems to believe that a "pink" reflex is the normal. Skeffington advises optometrists to give attention to the color of the reflection. This is a matter, he claims, demanding study and memory on the part of the optometrist. Skeffington has striven to record with pigments the characteristic colors revealed by differing eye conditions, but to date the attempt has been a failure. He also finds that it is difficult to describe shades of color in words so the attempt must be limited to generalizations. The normal, healthy cornea gives off, according to Skeffington, a clear, pinkish glow that is noted on his records as "corneal pink." When this color is seen through the telescope, the optometrist knows, according to Skeffington, that he has nothing pathologic to consider, and that it is just a case of simple refraction. But when the color deepens and shades from deep pink

to blurry red, Skeffington claims, that we have some of the various forms of blood congestion that may seriously effect our refractive work. High blood pressure, he feels, might cause this condition and suggests that the sphygmomanometer be utilized on such patients. Here again we find, in Skeffington's observations of this phenomenon, assertions made without the supporting evidence so necessary to substantiate the hypothesis, that these colored miral reflexes are symptomatic of pathology, ocular or otherwise.

McFadden[5], too, mentions this condition. He says in discussing the cornea let us respect it, study it, marvel at its faults as well as at its faultlessness, and above all let us give it the attention that is due. We have two common instruments, the ophthalmoscope and the ophthalmometer with which it can be given close analysis. With the latter, after having measured the major and minor meridians, we can back it off about one-fourth of an inch and get a reasonably good view of the epithelial layer, watch the tear-stream, see loose particles of dust, note the iridescent hue of the sebaceous liquid when the eye has been irritated by wind and weather, or other causes, as well as note whether the targets seem reflected upon a silver white surface or upon one tinged with pink. When the latter is noticed, McFadden claims, we will usually find an eye which is suffering from more or less irritation and lacrymation, with much unpleasantness. This is making the ophthalmometer do a double duty but it is one which it is reasonably well adapted to perform.

Ryer, already quoted, is found again referring to this subject in another of his writings[37], where he quotes from the New York optometrist, Drakeford, who made some observations that demand most careful consideration. Following an independent and very original line of observations, using at the time a Sutcliffe keratometer, Drakeford arrived at some rather startling conclusions. Drakeford's original notes are interesting and are here appended: "A healthy eye in a healthy person will give a clear and brilliant reflex—all outlines of mires being clear cut and definite. These are found mostly in hypermetropes of low degree where the person is young and vigorous. An eye which carries more or less inflammation of the tissues will show a reddish halo or atmosphere and a subdued reflex. Eyes of neurotics or those suffering from high nerve tension or inflammation of the nerves such as nervous prostration, will show a steel gray atmosphere and subdued moral reflexes. Myopes usually show a reddish atmosphere. I am now investigating the results of uric acid and kidney disorders on miral reflex condition." It remains to be added, says Ryer, that he has since made considerable advances along these lines, and it also seems well to call attention to this field for research and to urge that every optometrist contribute directly or indirectly by observing and recording every phenomenon bearing on this phase of the subject which presents itself in his individual practice. These observations by Drakeford and Ryer, present an interesting though as yet unsupported hypothesis.

The writer[14], in 1928, referred but briefly to this subject saying in a paper written at that time, as a rule the miral reflexes are white in color providing white mires are employed in the ophthalmometer but occasionally we find them tinged with color over their entire surface. This color may be of diagnostic value. It is therefore evident that a study of the literature of this subject reveals little or nothing of value. Certain optometrists and ophthalmologists who have observed the phenomenon have quite generally seemed to view it as an indication of ocular pathology, yet in none of these writings do they state upon what grounds they base their beliefs. The writer has observed these colored miral reflexes in one certain case now for eleven years. This case being under constant supervision with at least one annual ocular examination each year during this period. The patient is highly hyperopic but has shown no symptoms of ocular pathology and is, according to her physician, in good physical condition. Incidentally, this patient has not missed one day from her office on account of illness during this entire period. Yet this patient has a decided colored miral reflex when viewing the cornea through the ophthalmometer. The colors which predominate are lavender to red to pink and these colors are always present, irrespective of the lighting conditions in the room as the writer has attempted to change them by making an ophthalmometric examination with the room otherwise darkened. The writer realizes also that one case of this kind just mentioned, means little or nothing in viewing the entire matter and attempting to come to some sort of a conclusion. Whether or not pathology plays a part in the creation of these colored miral reflexes is a diagnostic point which can easily be cleared up by amassing a large number of clinical cases and keeping these under observation for some period of time. The writer suggests this as an interesting research problem to some local group of optometrists who wish to jointly engage in a useful and at the same time interesting bit of office investigation.

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BOOK NOTICES

THE PREVENTION AND CORRECTION OF READING DIFFICULTIES, Emmet A. Betts, Ph.D. Published by Row, Peterson and Company, Evanston, Ill. 402 pages, with a number of illustrations, cloth cover, 1936.

In writing this book Betts rendered a valuable service to both teachers and optometrists. The author contends that most reading diffi-

culties can be prevented if the causes can be properly determined and eradicated. This is not an easy task, as the causes are many and varied, and no one factor contributes to all types of reading difficulties.

Much of the contents of this book consists of original material gathered by Betts from the "Reading Clinic" at the State Normal School, Oswego, N. Y. He also reports extensively, of researches on this subject carried on by others. Each chapter is followed by a complete bibliography, which will be of assistance to the interested reader in studying more extensively any part of this fascinating and complex subject.

The author made extensive use of the Keystone Ophthalmic Telebinocular and the various types of slides produced by Keystone to be used in connection with the Telebinocular. Betts claims that from 8 to 25 per cent of all children in the elementary schools have reading difficulties. This reading deficiency retards general educational progress.

Several techniques are suggested to be used in cases with extreme reading difficulties. One of these is the visual approach. This is based upon the visual study of words. In this technique is utilized an outfit of carefully prepared material of various types. Words are introduced gradually and reused extensively. With each repetition the child becomes more attentive, observes more details, and perceives them more quickly and accurately, and thus works out the recognition of unfamiliar words, and acquires familiarity with new words in term of these visual elements.

This book will be great help to the optometrist who intends seriously to utilize his ophthalmograph and metronoscope in correcting reading disabilities, not only for the information on this subject given by the author but also, as I have already said, for the valuable and extensive bibliography given at the end of each chapter, which covers some special phase of this subject. J. I. K.

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ABSTRACTS

FOVEAL PROJECTION DURING DUCTIONS. Robert H. Peckham, Fellow, National Research Council. The Archives of Ophthalmology, XII, October, 1934, pp. 562-566.

AN OBJECTIVE STUDY OF BINOCULAR VISION. Robert H. Peckham, Temple University. The American Journal of Psychology, XLVIII, 3, July, 1936, pp. 474-479.

Peckham constructed an apparatus by which the movements of both eyes could be observed and measured during duction tests. The findings give much needed information. The collected data is in accord

with the findings of Clark in his photographic study of eye movements in stereoscopic vision. It is interesting to find two experiments, made independently, following different methods, with neither experimenter aware of what the other was doing, resulting in such agreement in data and conclusions.

The theory of ductions has been that the eyes turn as much as the images are displaced; that the turning is sufficient to bring the centers of the foveas to the centers of the images in order to maintain fusion and clear vision; that the visual axes must intersect in the object looked at; that when this amount of turning cannot be accomplished diplopia occurs; that if the images become blurred the accommodation is brought into retroflex activity because of changes in convergence brought about by the forced turning of the eyes. Many have questioned at least one of these items of the theory, some have questioned all. The results of the experiment give support to the questioners.

It appears that when one eye was induced to "duct" by the displacement of the image away from the fixation point, the usual response was: "the eye before the moving object turned in the same direction as the object, but through a smaller angle; the eye before the stationary object usually moved in the same direction as the other eye. This resulted in the stimulation of non-corresponding points by the images of the objects." But fusion was maintained, although the disparity thus produced was considerable and in some instances the images were undoubtedly on opposite sides of the foveas, i.e., one on the temporal side of its fovea and the other to the nasal side of its fovea.

Fusion was maintained in the induction (adduction) tests with a disparity in some cases as high as 7.5° and in the outduction (abduction) tests with a disparity of as high as 6.5°.

The results of the study are summarized as follows: (1) Fusion is possible when disparite or non-corresponding retinal points are stimulated. (2) No conclusions can be drawn from investigations of the relation between convergence and accommodation unless measurements are included in the eye-movements. (3) The results of the studies which have been made under the assumption that binocular fusion is evidence of the stimulation of corresponding retinal points are open to question. (4) The theory of a convergence function, or theoretical convergence-accommodation relationship, that depends upon the assumption of binocular fusion exclusively through the stimulation of corresponding retinal points, or near corresponding points, is fallacious. (5) The theory that the state of convergence in binocular fixation may be accomplished by two separate and independent monocular fixations is favored.

From the practicing refractionist's viewpoint, the significance of these objective studies of eye movements by various experimenters, all of whose reports are in substantial accord with the two reports here briefly summarized, may be stated as indicating support of Helmholtz's postulate that convergence is the result of two indendent monocular fixation

movements and throw considerable doubt on the nativistic theories of Hering and his school that convergence is a function of itself. The "blur-point" and "blur-out-point" theories that blur is only occasioned because of a change in accommodation is laid open to question, for with a monocular disparity as high as 3°, which is shown to be possible with fusion, there cannot be clear vision since acuity reduces sharply from the foveal center and is only 25% at 3° from the foveal center, calling the central foveal acuity 100%. The belief that the subjective report of blur in the duction tests shows an association of convergence and accommodation is unsupportable and is not in itself a valid diagnostic point. These objective studies of the vergence movements, in calling attention to the fact that subjective investigations in which blur is interpreted as proof of accommodative change are not valid data, further awaken the thought that an equally definite objective method of watching accommodative changes during ductions is needed. Ray Morse-Peckham.